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Recent Progress of the Compact Pulsed Hadron Source Project and Related Activities at Tsinghua University

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Abstract

The Compact Pulsed Hadron Source (CPHS), currently under construction at Tsinghua University, will generate a yield of ~ 10^{13} n/s epithermal-to-cold neutrons for education, instrumentation development, and industrial applications around the year of 2013. Here, we report the progress on the design, fabrication, and engineering of the proton accelerator system, the neutron target station and neutron beamlines.

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Keywords:

1. Introduction

The Department of Engineering Physics (DEP) of Tsinghua University undertakes the Project of building the Compact Pulsed Hadron Source (CPHS), the first multi-purpose pulsed neutron source in China, to acquire the knowledge base and to realize the implementation of proton accelerators, neutron-producing target & moderators, and neutron-scattering & radiography instruments for materials characterization. The relatively low proton power and moderate neutron flux of CPHS allow employment of in-house designed and domestically produced compact instrumentation modules according to an expedient construction schedule. This approach presents several advantages: 1) The neutron imaging/radiography station (NIRS) and small-angle neutron scattering instrument (SANS) will form a basic experimental platform for neutron user training and rudimental research before Chinas major neutron facilities, e.g., the China Spallation Neutron Source (CSNS), are open for operation; 2) The construction, commissioning and develop-

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ment of various accelerator and neutronic hardware complement DEPs ongoing R&D program in nuclear instrumentation; and 3) CPHS will augment the Tsinghua Thomson X-ray (TTX) Source, a nearby DEPs electron beam and hard x-rays research facility, as support structures for the Scientific Facility for Advanced Quantum Probes at Tsinghua University. To proceed with the Project which is funded entirely by Tsinghua University, DEP draws the workforce mainly from the departmental staff and seeks assistance from various external expert research and technical groups from national laboratories, universities and industry. Of equal importance is the networking with the international accelerator and neutron community for consultation and collaboration.

An overview of the CPHS, the design and operation parameters of the accelerator system, the neutron target station, experimental beamlines, controls and conventional facilities at the pilot stage of the Project were described in an earlier paper [Loong et al. (2012)]. Here, we present a mid-term progress report of the Project, emphasizing the aforementioned game plan and numerous contributions that we received from collaborators. Details of the prototyping, test results, and expected performance of different systems can be found in cited references.

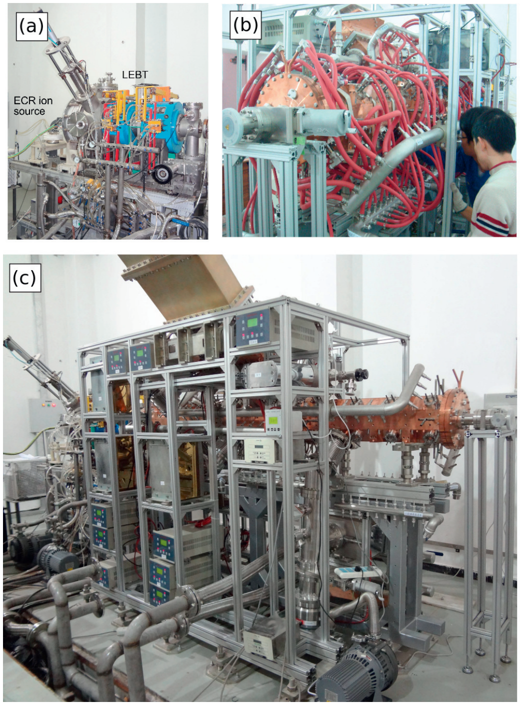
2. Progress in 2010-2012

Each system is led by a designated team that is in charge of the technical design, engineering evaluation, procurement and fabrication, installation and testing, and commissioning. Project management calls for various kinds of internal and external reviews, organizes focused workshops and taskforces for problem-solving, implements budget and work-breakdown controls, facilitates contract negotiation and procurement processes, and sets up interfacing between different organizations.

The accelerator system consists of the ion source (IS), a 4-vane 3-MeV/50-mA radio frequency quadrupole (RFQ) proton accelerator, drift tube linac (DTL), RF power supply and distributor, and beam transport. The high-intensity, electron-cyclotron-resonance (ECR)-type IS and the low-energy beam transport (LEBT) were fabricated at the Institute of Modern Physics (IMP) of the Chinese Academy of Sciences (CAS). After delivery and installation, the system underwent tuning and testing and is deemed ready for commissioning. The RFQ team includes researchers from DEP (Q-Z Xing et al.), engineers from the NUCTECH Co Ltd. (J. Li et al.), and experts from the USA (J. Billen, J. Stovall, and L. Young). They supervise the manufacture of the RFQ and progressive benchmark tests at the Kelin Co. Ltd in Shanghai, undertake the installation of the completed product at CPHS and have obtained satisfactory results from a cold test of the RFQ accelerator [Xing et al.]. The rectification of a material problem that caused leakage in a RFQ flange during fabrication at Kelin and an erroneous specification in the RF power transmission system committed by the supplier, AFT in Germany, have impacted a 6-month delay in the accelerator installation. Currently, we anticipate the commissioning of the IS, LEBT, and proton RFQ for production of 3 MeV protons in early 2013. The fabrication of the DTL accelerator that will increase the proton energy to 13 MeV is ongoing at Tsinghua University. Figure 1 shows the setup of the IS, LEBT, and RFQ segments.

2.1. Neutron beamlines [Huang et al. (2012)]

Two neutron beams are to be built for imagingthe NIRS and small-angle scatteringthe SANS. This corresponds to two PhD thesis projects, respectively, for S. F. Su of Sun Yat-Sen University and T.C. Huang of DEP who have received substantial help from faculty and staff of DEP. The SANS team also works closely with the instrument scientist and engineers from the Institute of High Energy Physics (IHEP), CAS who are building an SANS beamline for CSNS. The upstream beam tubes and collimation with shielding coverage have been designed and built. We expect to install the shielded hut that houses the sample positioning and translation unit, and the neutron camera and image-plate device in 2013, in parallel with the work of commissioning proton and neutron production. With regard to the SANS beamline, the design calls for a detector bank comprising about 80 He-3 linear position-sensitive detectors (LPSD) (each of 1000 mm in length and 12 mm in diameter). Although we successfully fabricated two He-3 LPSDs and developed the associated electronics, we are hesitant about the construction of the scattering chamber that is specifically



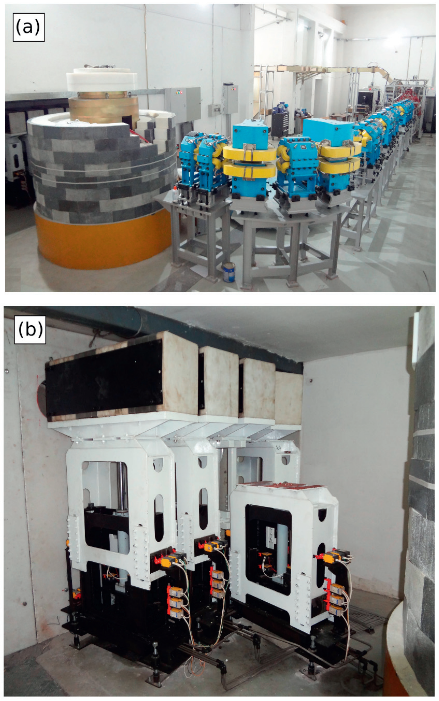


Fig. 1. (Left) (a) The ECR ion source and the LEBT unit, (b) The naked RFQ, and (c) the RFQ with water cooling connected. The cold tests of the RFQ indicated a less than 2% error in the quadrupole field and the admixture of the two dipole modes with respect to the designed values.

Fig. 2. (right) (a) The neutron target station with proton-beam entrance from the right and neutron exit in the downstream forward direction, and (b) the shutters of the four neutron beam ports located between the biological shield barrier and the target station.

designed for using He-3 LPSDs due to the uncertainty of worldwide He-3 gas supply. Currently we are weighing the options of detector types and the impact on SANS performance. Meanwhile we are actively pursuing development of neutron detectors based on non-He-3 technologies. Other peripheral apparatuses such as neutron bandwidth selecting choppers and low-efficiency beam monitors have been prototyped.

2.2. Detector Development

In addition to the work on fabrication of He-3 gas proportional counters, we have carried out R&D of gadolinium-doped micro-channel plate (MCP) and boron-lined gaseous detectors. The effort has intensified recently by virtue of an independently funded program. Naturally, the detector team works in parallel with the CHPS Project and coordinates the results with the world community of neutron detector development. For example, the collaboration with the HUNS facility of Hokkaido University in personnel exchange and equipment testing has produced fruitful results. In both cases the neutron conversion efficiency, signal amplification, and spatial resolution depend on the thickness of the dopant or coating layers, which in turn dictate the methodology of fabrication and electronic read-out. First, the detector performance is assessed by simulations which point to a preferred structure and configuration. We then decide the method of fabrication and develop a prototype, followed by neutron testing. Chemical impregnation of Gd doping and electron beam evaporation techniques have been chosen for the MCP and natural B4C-coated straw-tube-type detectors, respectively. Preliminary tests, which show promising results for the MCP detectors, are described elsewhere [Pan et al. (2013)]. After neutron production is realized at CPHS, we plan to make use of the spare beam ports and construct rudimental beamlines for neutron detector and device development.

3. Concluding Remarks

he CPHS Project that started from scratch in late 2009 has made significant progress in the last two years. The ion source, RFQ accelerator, RF power-supply and beam-transport systems are ready for start-up tests of 3-MeV protons. All the major components of the neutron target station, Be target housing and cooling system, the starting moderator and reflector, neutron beam shutters, and target-station and biological shielding are in place to receive protons and to monitor neutron production. The development of the imaging NIRS is ahead of that of the SANS beamline. Major building of the beamlines will be carried out in parallel with the commissioning of proton and neutron production. The Project has been benefited from collaborations with neutron-source laboratories and universities, domestic and international. We shall continue to work with the neutron and accelerator communities with emphases on device development and scientific applications of using neutrons and protons.

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Note added to proof

The first 3-MeV proton beam (pulse width ~ 50 microsecond) was achieved at CPHS on March 25, 2013 with a beam transmission efficiency of 88%.

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